CLAIMS

Therefore, at least the following is claimed:

1. A membrane, comprising:

a flexible proton electrolyte membrane having the characteristic of a proton conductivity of about 1×10^{-6} to 1×10^{-1} S/cm at a temperature range of about 30°C to about 180°C and a relative humidity of about 0% to 100%.

2. A fuel cell, comprising:

a flexible proton electrolyte membrane having the characteristic of a proton conductivity of about 1×10^{-6} to 1×10^{-1} S/cm at a temperature range of about 30°C to about 180°C and a relative humidity of about 0% to 100%; with the proviso that the fuel cell does not include a humidifier, a catalyst, and a thermal management system for controlling the temperature in the fuel cell.

3. A flexible proton electrolyte membrane, comprising:

a hybrid inorganic-organic copolymer network having at least one backbone unit having a formula [-O-Si(WX)-O-Si(YZ)-R^1-], wherein each of W, X, Y, and Z is selected from -OPO_3H_2, -R^2A, -R^3, -O-, and –OPO_3H_2, and wherein R^1, R^2, and R^3 are each hydrocarbons.

4. The membrane of claim 3, wherein R^1 is selected from a linear C_2 to C_{20} hydrocarbon, a branched C_2 to C_{20} hydrocarbon, a halogen-substituted linear C_2 to C_{20} hydrocarbon, and a halogen-substituted branched C_2 to C_{20} hydrocarbon.

5. The membrane of claim 3, wherein R^2 is selected from a linear C_2 to C_{20} hydrocarbon, a branched C_2 to C_{20} hydrocarbon, a hydrocarbon including an aromatic ring, a halogen-substituted linear C_2 to C_{20} hydrocarbon, a halogen-substituted branched C_2 to C_{20} hydrocarbon, and a halogen-substituted hydrocarbon including an aromatic ring.

6. The membrane of claim 3, wherein R^3 is selected from CH_3 and C_2H_5.

7. The membrane of claim 3, wherein A is selected from $-SO_3H$, $SO_2NHSO_2CF_3$, $-CF_2SO_3H$, and $-CF_2SO_2NHSO_2CF_3$.

8. The membrane of claim 3, wherein the backbone unit is crosslinked with a second backbone unit.

9. The membrane of claim 3, wherein each of W, X, Y, and Z are different.

10. The membrane of claim 3, wherein the backbone unit has a formula [-O-Si(WX)-O-Si(YZ)-R^1-O-R^4], wherein each of W, X, Y, and Z is selected from, -R^2A, -R^3, -O-, and $-OPO_3H_2$, wherein R^4 is a hydrocarbon.

11. The membrane of claim 10, wherein R^4 is selected from a linear C_2 to C_{20} hydrocarbon, a branched C_2 to C_{20} hydrocarbon, a halogen-substituted linear C_2 to C_{20} hydrocarbon, and a halogen-substituted branched C_2 to C_{20} hydrocarbon.

12. The membrane of claim 3, wherein the backbone unit has a formula [-O-Si(WX)-O-Si(YQ)-R^1-Si(YQ)-], wherein each of W, X, and Y is selected from -OPO_3H_2, -R^2A, -R^3, -OPO_3H_2, wherein Q includes -O-Si-R^8-Si- wherein R^2 and R^3 are each hydrocarbons, wherein each of R^1 and R^8 are selected from a short chain hydrocarbon and a long chain hydrocarbon, wherein R^1 and R^8 are different, wherein the short chain hydrocarbon is selected from a linear C_2 to C_{20} hydrocarbon, a branched C_2 to C_{20} hydrocarbon, a halogen-substituted linear C_2 to C_{20} hydrocarbon, and a halogen-substituted branched C_2 to C_{20} hydrocarbon, and wherein a long chain hydrocarbon is selected from a hydrocarbon having a molecular weight from about 500 to 100,000 and a halogen-substituted hydrocarbon having a molecular weight from about 500 to 100,000.

13. The membrane of claim 3, wherein the membrane is incorporated in a fuel cell.

14. A membrane formed from mixing components comprising:

at least one hybrid inorganic-organic copolymer network former compound;

a first compound including an inorganic acid group;

a Si-O-Si inorganic backbone former compound; and

a H_3PO_4 compound.

15. The membrane of claim 14, wherein the inorganic acid group is selected from $-SO_3H$, $-SO_2NHSO_2CF_3$, $-CF_2SO_3H$, and $-CF_2SO_2NHSO_2CF_3$.

16. The membrane of claim 14, wherein the hybrid inorganic-organic copolymer network former compound includes an epoxide ring containing alkoxysilane compound.

17. The membrane of claim 16, wherein the epoxide ring containing alkoxysilane compound is selected from an aliphatic epoxide ring containing alkoxysilane compound and a cycloaliphatic epoxide ring containing alkoxysilane compound.

18. The membrane of claim 17, wherein the epoxide ring containing alkoxysilane compound is selected from $(D_{3-x}M_x)SiR^5C_2H_3O$ and $(D_{3-x}M_x)SiR^5C_6H_9O$, wherein D can be selected from C_2H_5O and CH_3O, M is selected from C_2H_5 and CH_3, R^5 is a C_2 to C_{20} hydrocarbon chain, and x is from 0 to 2.

19. The membrane of claim 17, wherein the epoxide ring containing alkoxysilane compound is selected from (3-glycidoxypropyl)methyldiethoxysilane, (3-glycidoxypropyl)methyldimethoxysilane, (3-glycidoxypropyl)triethoxysilane, (3-glycidoxypropyl)trimethoxysilane, 5,6-epoxyhexyltriethoxysilane, 5,6-epoxyhexyltrimethoxysilane, 2-(3,4-epoxycyclohexyl)ethyltriethoxysilane, and 2-(3,4-epoxycyclohexyl)ethyltrimethoxysilane.

20. The membrane of claim 14, wherein the hybrid inorganic-organic copolymer network former is selected from an aliphatic diepoxide monomer and a cycloaliphatic diepoxide monomer.

21. The membrane of claim 20, wherein the hybrid inorganic-organic copolymer network former is selected from $(C_2H_3O)R^6(C_2H_3O)$ and $C_6H_9OR^6C_6H_9O$, wherein R is a C_2 to C_{20} hydrocarbon chain.

22. The membrane of claim 20, wherein the hybrid inorganic-organic copolymer network former is selected from 1,3-butadiene diepoxide, dicyclopentadiene diepoxide, and 3,4-epoxycyclohexylmethyl-3,4,-epoxy-cyclohexanecarboxylate.

23. The membrane of claim 14, wherein first compound including an inorganic acid group includes $(D_{3-x}M_x)SiR^7A$, wherein D can be selected from C_2H_5O and CH_3O, M is selected from C_2H_5 and CH_3, R^7 is a C_2 to C_{20} hydrocarbon chain, x is from 0 to 2, and wherein A is an inorganic acid group is selected from $-SO_3H$, $-SO_2NHSO_2CF_3$, $-CF_2SO_3H$, and $-CF_2SO_2NHSO_2CF_3$.

24. The membrane of claim 14, wherein the first compound including an inorganic acid group is selected from sulfonated phenyltriethoxysilane (SPS), sulfonated phenylethyltriethoxysilane, and 3-(trihydroxysilyl)-1-propane sulfonic acid.

25. The membrane of claim 14, wherein the Si-O-Si inorganic backbone former compound is selected from tetraethoxysilane and tetramethoxysilane.

26. The membrane of claim 14, wherein the hybrid inorganic-organic copolymer network former compound is from about 20 to 80 mole ratio of the membrane, the first compound including an inorganic acid functional group is from about 0 to 20 mole ratio of the membrane, the Si-O-Si inorganic backbone former compound is from about 20 to 80 mole ratio of the membrane, and the H_3PO_4 compound is about 0.1 to 1.5 times the total Si moles in the membrane.

27. A membrane formed from mixing components comprising:

a bis(alkylalkoxysilyl)-terminated polymer compound;

a bis(trialkoxysilyl)-terminated short organic chain compound;

a first compound including an inorganic acid group;

a Si-O-Si inorganic backbone former compound; and

a H_3PO_4 compound.

28. The membrane of claim 27, further comprising a heterocycle compound.

29. The membrane of claim 28, wherein the imidazole-ring containing compound is selected from imidazole, benzimidazole, 2-phenyl imidazole (PI), 2-methyl 4-ethyl imidazole, and imidazole-2-carboxaldehyde.

30. The membrane of claim 27, wherein the bis(alkylalkoxysilyl)-terminated polymer compound includes $(D_{3-x}M_x)SiR^9Si\ (D_{3-x}M_x)$, wherein D can be selected from C_2H_5O and CH_3O, M is selected from C_2H_5 and CH_3, R^9 is a linear C_2 to C_{20} hydrocarbon chain, and x is from 1 to 2.

31. The membrane of claim 30, wherein the bis(alkylalkoxysilyl)-terminated polymer compound is selected from bis((3-methyldimethoxysilyl)propyl)polypropylene oxide, bis((3-methyldimethoxysilyl)propyl)polytetraethylene oxide, bis(methyldimethoxysilyl)poly(1-butene), bis(methyldimethoxysilyl)polyethylene, bis(dimethylmethoxysilyl)polyethylene, bis(methyldimethoxysilyl)polypropylene, bis(methyldimethoxysilyl)polyvinylidene fluoride, bis(methyldimethoxysilyl)polystyrene, bis(methyldimethoxysilyl)polytetrafluoroethylene, bis(methyldimethoxysilyl)polyvinyl chloride, and bis(methyldimethoxysilyl)polyvinyl alcohol.

32. The membrane of claim 27, wherein the bis(trialkoxysilyl)-terminated short organic chain compound includes $(D_3)SiR^{10}Si(D_3)$, wherein D can be selected from C_2H_5O and CH_3O, R^{10} is a linear C_2 to C_{20} hydrocarbon chain, and x is from 1 to 2.

33. The membrane of claim 32, wherein the bis(alkylalkoxysilyl)-terminated polymer compound is selected from bis(triethoxysilyl)ethane, bis(triethoxysilyl)octane, bis(triethoxysilyl)nonane, bis(triethoxysilyl)methane, bis(triethoxysilylethyl)benzene, bis(triethoxysilyl)hexane, bis(trimethoxysilylpropyl)amine, bis[(trimethoxysilyl)propyl)]ethylenediamine, bis(trimethoxysilyl)ethane, bis(trimethoxysilyl)octane, bis(trimethoxysilyl)nonane, bis(trimethoxysilyl)methane, bis(trimethoxysilylethyl)benzene, and bis(trimethoxysilyl)hexane.

34. The membrane of claim 27, wherein the first compound including an inorganic acid group includes $(D_{3-x}M_x)SiR^{11}A$, wherein D can be selected from C_2H_5O and CH_3O, M is selected from C_2H_5 and CH_3, R^{11} is a C_2 to C_{20} hydrocarbon chain, x is from 0 to 2, and wherein A is an inorganic acid group is selected from $-SO_3H$, $-SO_2NHSO_2CF_3$, $-CF_2SO_3H$, and $-CF_2SO_2NHSO_2CF_3$.

35. The membrane of claim 27, wherein the first compound including an inorganic acid group is selected from sulfonated phenyltriethoxysilane (SPS), sulfonated phenylethyltriethoxysilane, and 3-(trihydroxysilyl)-1-propane sulfonic acid.

36. The membrane of claim 27, wherein the Si-O-Si inorganic backbone former compound is selected from tetraethoxysilane and tetramethoxysilane.

37. The membrane of claim 27, wherein the membrane includes about 1 to 2 moles of Si derived from the bis(alkylalkoxysilyl)-terminated polymer compound, about 0 to 3 moles of Si derived from the bis(trialkoxysilyl)-terminated short organic chain compound, about 0 to 3 moles of Si derived from the first compound including an inorganic acid group, about 0 to 2 moles of Si derived from the Si-O-Si inorganic backbone former compound, and wherein about 10% to 150% of the moles of Si from the bis(alkylalkoxysilyl)-terminated polymer compound, bis(trialkoxysilyl)-terminated short organic chain compound, the first compound including an inorganic acid group, the Si-O-Si inorganic backbone former compound, equals the moles of H_3PO_4.

38. The membrane of claim 28, wherein the membrane includes about 1 to 2 moles of Si derived from the bis(alkylalkoxysilyl)-terminated polymer compound, about 0 to 3 moles of Si derived from the bis(trialkoxysilyl)-terminated short organic chain compound, about 0 to 3 moles of Si derived from the first compound including an inorganic acid group, about 0 to 2 moles of Si derived from the Si-O-Si inorganic backbone former compound, about 50% to 100% of the moles of Si from the bis(alkylalkoxysilyl)-terminated polymer compound, bis(trialkoxysilyl)-terminated short organic chain compound, the first compound including an inorganic acid group, the Si-O-Si inorganic backbone former compound, equals the moles of H_3PO_4, and about 0% to 50% of the moles of H_3PO_4 equals the moles of the heterocyle compound.

39. A method of preparing a membrane comprising:

providing a sol mixture, wherein the sol mixture is from formed by mixing compounds selected from group 1 or group 2, wherein group 1 comprises at least one hybrid inorganic-organic copolymer network former compound, a first compound including an inorganic acid group, a Si-O-Si inorganic backbone former compound, and a H_3PO_4 compound, and group 2 comprises a bis(alkylalkoxysilyl)-terminated polymer compound, a bis(trialkoxysilyl)-terminated short organic chain compound, a first compound including an inorganic acid group, a Si-O-Si inorganic backbone former compound, and a H_3PO_4 compound;

disposing the mixture on a substrate;

heating the mixture; and

forming a flexible proton electrolyte membrane having the characteristic of a proton conductivity of about 1×10^{-6} to 1×10^{-1} S/cm at a temperature range of about 30°C to about 180°C and a relative humidity of about 0% to 100%.